Zero-G Corp.
May 2012 Campaign

May 10-18, 2012

Ellington Field, TX

Manifest

- 005-P Two-Phase Space Heat Exchangers Design Tools – Jungo Kim
- 011-P Cryocooler Vibrational Characterization – Ben Longmier
- 014-P Heat Pipe Limits in Reduced Gravity Environments – Marc Gibson
- 025-P Vestibulo-Ocular Function – Mark Shelhamer
- 026-P Evaluation of Medical Chest Drainage System in uG – Marsh Cuttino
- 027-P Cell Culture Apparatus – Zarana Patel
- 028-P Non-invasive acquisition of physiologic variables – Ravi Komatireddy
- 042-P OSIRIS-REx Low-Gravity Regolith Sampling Tests – Joe Vellinga

005-P Development and Validation of Design Tools for Advanced, Two-Phase, Space Heat Exchangers

STATUS QUO

- **Single phase heat exchangers are currently used for cooling on ISS and other space platforms.**
- **Two-phase heat exchangers can be more compact, more efficient , and lower weight**
- **Questions regarding the effect of gravity on two-phase heat exchanger performance prevent their use.**
- **Current methods of measuring heat transfer during flow boiling are limited to area averaged heat transfer and temperature.**

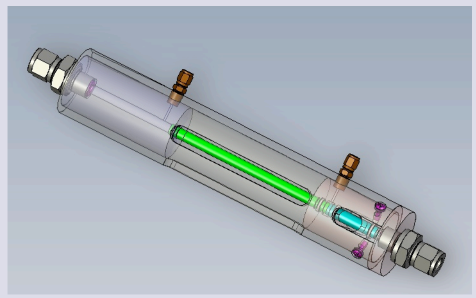
NEW INSIGHTS

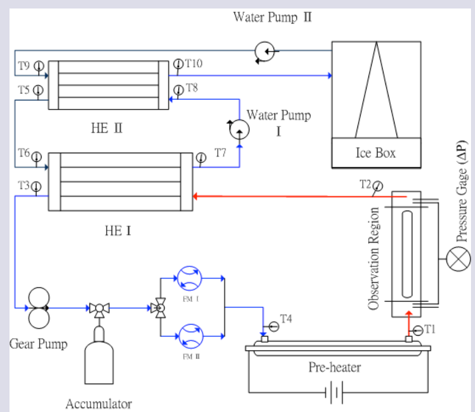
Technology Focus Area: Fluid Physics

A silicon tube 6 mm ID and 1 mm wall thickness is used in con-junction with an IR camera to measure temperature distributions on the wetted wall and to visualize the flow. Half the inner circum-ference is coated with a black opaque paint and the other half is left clear. Mirrors are used to obtain temperature and flow visualization simultaneously.

TEST APPARATUS OVERVIEW:

A closed flow loop has been constructed whereby flow boiling measurements can be made in low-g environments. The experiment is contained within a single test rack (100 cm wide x 750 cm high x 650 cm deep) bolted to the floor of the aircraft. The mass of the apparatus is about 118 kg.





QUANTITATIVE IMPACT

Requested Zero-G conditions

- Up to 30 1.8 g to zero-g parabolas per day
- 4 days of flying

Test Parameters to be varied

- Heater power
- Inlet liquid subcooling
- Inlet mass flow rate
- Heater power

No. of Personnel:

- 3 test personnel per flight

END-OF-PHASE GOAL

Project Impact:

- Results of the tests will allow current models of flow boiling to be tested using local data.
- The data will help develop criterion that will allow the effects of gravity on boiling to be quantified
- The appropriate velocity above which gravity effects can be neglected will be determined

The current experiment allows the local temperatures and heat transfer to be measured with unprecedented spatial and temporal resolution, allowing flow boiling models to be verified.

011-P Cryocooler Vibration Analysis for VF-200

Rocket Company

ASTRA

STATUS QUO

Sunpower CryoTel™ (CT) cryocooler testing to date.

- Prior μg campaigns, SEED 2010 and FAST 2010, establish commercial technology at TRL 6.
- Thermal testing of CT cryocooler testing in-situ with High Temperature Super Conducting (HTSC) magnet presented need for vibration mitigation at CT-HTSC interface.

Significance of Study:

Vibration characterization

NEW INSIGHTS

Ad Astra's VF-200, VASIMR® (Variable Specific Impulse Magnetoplasma Rocket) Flight - 200 kW, scheduled for testing aboard the ISS in 2014, nozzles plasma propellant via a core of mechanically sensitive HTSC magnets, conduction cooled by CT cryocoolers. Investigation of CT vibration modes will advance TRL of cryocooler technology while simultaneously down selecting mounting interface design.

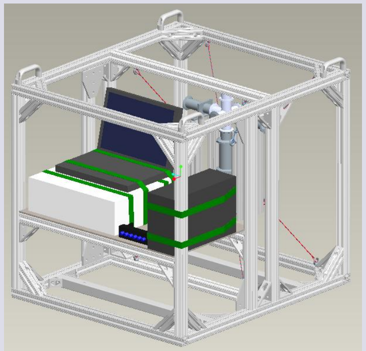
VIBRATION ANALYSIS ACHIEVEMENT

OVERALL OBJECTIVE:

The SunPower CryoTel™ (CT) model cryocooler is a compact Stirling engine device capable of rejecting 10-15 Watts at 40K, ideal for the baseline VF-200. Significant vibrations induced by CT operation pose a hazard to system integrity by degradation of the High Temperature Superconducting (HTSC) magnetic field. The study will advance a solution to mitigate this problem by furthering understanding of CT vibrational characteristics. The experiment is designed to isolate the CT mass system from the experiment frame, reducing the uncertainty associated with vibration transfer.

TEST METHOD:

3-axis accelerometers strategically instrumented throughout experiment provide comprehensive vibration responses at varying cryocooler power levels. Cryocooler operation monitored by current and temperature measurements.



CAD model of experiment rig

QUANTITATIVE IMPACT

Flight Requirements:

Parabola Requirements: 40 parabolas/flight x4flights. 10^{-3} G's to 2 G's parabolic profile.

Vibration Measurement:

Accelerometer specifications: Adjustable sensitivity: ±3g or ±11g Supply voltage: 2.2 V-16 V Supply current: 0.5 mA

Experiment Interfaces:

Mode of Operations: Autonomous, LabVIEW controlled. *Power requirements:* 115 VAC.

Experiment Specifications: *Mass/ Dimensions:* 220 lbs. 33in. x 33in. 37.5in.

END-OF-PHASE GOAL

Measure vibrational characteristics of cryocooler operation.

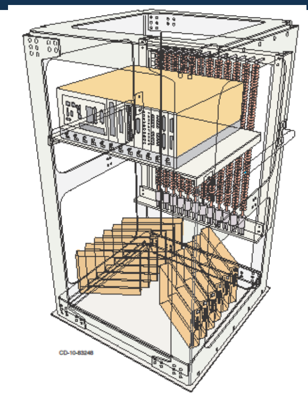
- Determine natural frequency and intensity of vibrations as a function of test parameters (cryocooler power, g-load, mounting arrangement)
- Offer initial design solution for vibration mitigation.

Sunpower Cryotel™ platform will provide lightweight and compact cryocooling capabilities for the VF-200 test flight aboard the ISS in 2014.

Fission Power Systems

014-P Thermosyphon Array with Controlled Operation (TACO)

STATUS QUO



Thermosyphon Array with Controlled Operation (TACO)

NEW INSIGHTS

Technology Focus Area:
Heat Pipes as Thermosyphons

Specific Benefits of Technology: **Improved radiator technology for cooling fission power systems**

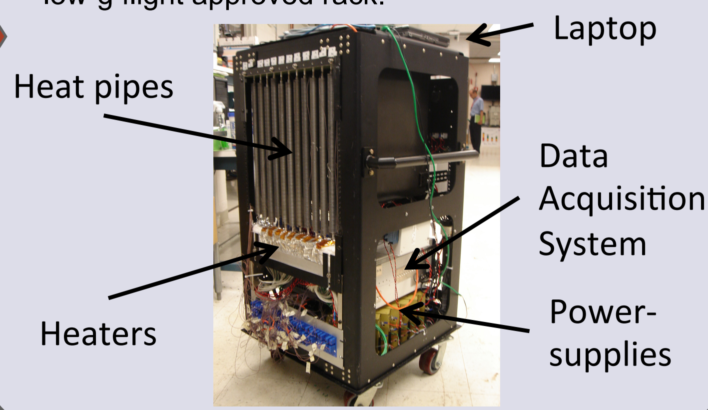
Data regarding the flooding limit of heat pipes operating as thermosyphons is traditionally gathered at Earth gravity (1g). To design thermosyphons that will work in a reduced gravity environment, more data needs to be collected regarding the flooding limit in a low-g environment.

MAIN ACHIEVEMENT:

The TACO will provide thermosyphon flooding limit data that can be used to validate flooding limit modeling for reduced gravity environments. Data will be gathered for the simulated gravitational accelerations of the moon (1/6g) and Mars (1/3g).

HOW IT WORKS:

The experiment consists of 12 vertically oriented heat pipes (thermosyphons) that are heated by a series of cartridge heaters. The heaters are controlled by a laptop, and the temperatures of the heat pipes are monitored by thermocouples. A heat pipe has flooded when a spike in the evaporator temperature is observed. All equipment is neatly contained in an aluminum, low-g flight approved rack.



QUANTITATIVE IMPACT

Flight Measurement Requirements:

- Flooding limit measurements at 1/6g and 1/3g

Power Requirements:

- 4x115 VAC outlets
- Total Current: 51 Amps
- Total Power: 5865 Watts

Experiment Specifications:

- Dimensions (L,W,H): 24.0, 24.0, 42.19 [in]

Weight: 270 [lbs]

END-OF-PHASE GOAL

Record thermosyphon flooding limit data in reduced gravity

- *Develop an accurate model to predict the onset of flooding in a closed two-phase thermosyphon*
- *Utilize model to design heat pipes that can be used as part of a surface fission power system for the moon or Mars.*

The Thermosyphon Array with Controlled Operation (TACO) is a fully contained, semi-autonomous system designed to provide data regarding thermosyphon operation in a low-g environment.

025-P

Assessing Vestibulo-Ocular Function and Spatial Orientation in Parabolic Flight

Problem Statement

- As defined by the NASA Human Research Program: there is a need for "a new, innovative, hand-held smart-device requiring minimal power and mass for assessment and rehabilitation of crewmembers on lunar and Mars surfaces."
- Our device will fulfill this need for rapid sensorimotor assessment.
- Parabolic flights provide space-relevant g levels for testing, and induce sensorimotor changes similar to those of space flight.
- Potential users: NASA astronauts, flight surgeons. Others requiring sensorimotor assessment in the field.

Technology Development Team

- PI: Mark Shelhamer, Johns Hopkins University School of Medicine, mjs@dizzy.med.jhu.edu.

- Funding: NASA HRP.
- Technology partners: none.

Proposed Flight Experiment

Experiment Readiness:

- Ready for flight May 2012.

Test Vehicles:

- Parabolic aircraft.

Test Environment:

- Previous versions (different hardware) flew in parabolic flight in 2010 and 2011. Testing is requested in all available g levels (0, 1.8, lunar).

Test Apparatus Description:

- Tablet computer: presents visual display, records motion, accepts user input through touch screen.
- Wireless motion sensors: record user motion.
- Red/Green goggles: binocular display presentation
- Blac

Technology Maturation

- Current TRL: 4 *component and/or breadboard validation in laboratory environment*.
- TRL 5 *validation in relevant* environment – flights in 2012 & 2013 to verify proper operation of components for sensorimotor assessment, user interfacing.
- TRL 6 *demonstration in relevant environment* – flights in 2013 & 2014 with integrated hardware & software; modifications based on previous flight experience.
- TRL 6 deadline: August 2014.

Objective of Proposed Experiment

- 1) determine if test subject can use device quickly and easily, 2) determine if assessment tests implemented on device are sensitive enough to detect sensorimotor changes induced by flight.
- Data will be obtained on device functionality (measurement of sensorimotor changes), and user interface (reporting of sensorimotor perceptions). Any deficiencies in these areas will lead to redesign and re-flight.

Technology Areas addressed by this technology: TA06: Human Health, Life Support and Habitation Systems

026-P Evaluation of a Medical Chest Drainage System Functional in the Microgravity Environment

Problem Statement

- If an astronaut experiences a collapsed lung (pneumothorax), medical suction is required to inflate the lung through a thoracic chest tube. This requires a medical chest drain and suction.
- Medical suction clears the airway, empties the stomach, decompresses the chest, and keeps operative fields clear.
- There is currently no medical suction capability that would work in the microgravity environment. Current medical thoracic suction is dependant upon gravity and fluid to operate.
- End users of the mature technology include hospitals, aeromedical transport, and military medicine.

Technology Development Team

- C. Marsh Cuttino, MD
  Orbital Medicine, Inc
  Orbitalmedicine@gmail.com

- Funded by Orbital Medicine

- Stanford University
  Purdue University
  Atrium Medical

Proposed Flight Experiment

Experiment Readiness:

- The experiment will be ready for flight May 2012.

Test Vehicles:

- The preferred test vehicle is the parabolic aircraft. Future iterations would benefit from the longer period of microgravity available in sRLV's when they are available.

Test Environment:

- This experiment is pending parabolic flight.

Test Apparatus Description:

- The experimental system includes a suction pump, a modified commercial dry suction chest drainage system, and a thoracic chest tube placed in a pneumothorax simulator.
- The system includes suction gages to monitor vacuum fluctuations, and photographic analysis of the system during parabolic flight will determine the effectiveness of four configurations of biologic fluid entrapment mechanisms.

Technology Maturation

- The testing in parabolic flight will allow confirmation of the basic technology elements in a representative environment for TRL 5.
- Computational Flow Dynamics will be used to optimize the final design and complete final integrated engineering.
- Evaluation of configuration and optimization with repeated testing and consolidated construction will allow for progression to TRL 6.

Objective of Proposed Experiment

- The objective of the experiment is to demonstrate suction and determine the capability of the device to isolate biological fluids into a suction canister in microgravity.
- The May 2012 flight will demonstrate the proof of concept. The parabolic flights will be used to select the optimum configuration of fluid containment and verify feasibility of medical dry suction.

Human Research Roadmap: Inability to Adequately Recognize or Treat an Ill or Injured Crew Member:
EXMC 4.09: Lack of medical suction and fluid containment capability for chest tube and airway management.

027-P Autonomous Cell Culture Apparatus for Growing 3-Dimensional Tissues in Microgravity

Problem Statement

- Currently, there are almost no methods by which researchers can grow 3-D human epithelial tissues in microgravity to study the multiple hazards that long duration spaceflight poses to human health. To better understand and mitigate these risks, we are developing equipment that can culture these 3-D models in zero-g and maintain the air-liquid interface they require for proper growth.
- This flight opportunity will help mature the technology by allowing us to test the equipment modifications and upgrades, with all subsystems, in a relevant zero-g environment.
- Potential users include life science investigators interested in conducting research on 3-D epithelial cultures (of lung, esophagus, oral cavities, colon as well as others) in microgravity

Technology Development Team

- **PI**: Zarana Patel, PhD
  Universities Space Research Assoc.
  zarana.s.patel@nasa.gov

Funding:

- Yale University: Science & Engineering Assoc. (cerro@aya.yale.edu), Physics Dept. (meg.urry@yale.edu), Science Council (william.segraves@yale.edu), Dean's Office
- Connecticut Space Grant Consortium (ctspgrant@hartford.edu)

Proposed Flight Experiment

Experiment Readiness:

- April 2012

Test Vehicles:

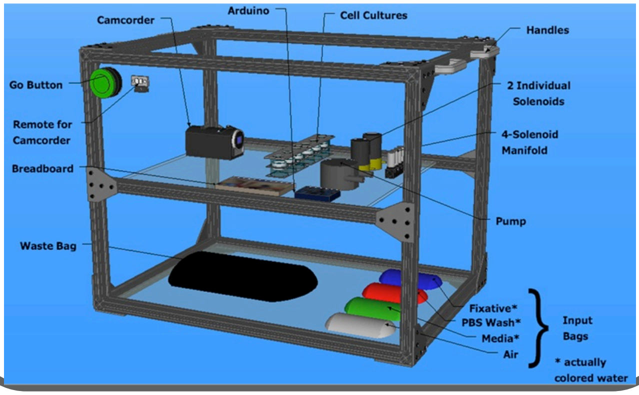
- Parabolic aircraft for initial testing
- SRLVs for higher level testing to mature the technology

Test Environment:

- 2010 – Flown on parabolic aircraft in April 2012 through RGSFOP SEED program
- 2012 – Scheduled to fly May 2012 on parabolic aircraft through NASA FOP

Test Apparatus Description:

- The cell culture compartments consist of 6 removable mesh inserts placed into a well-plate array of 6 separate compartments, with an upper and a lower chamber that air and liquid can flow through. A peristaltic pump and solenoid valves act to create an air-liquid interface over the cell culture within the mesh insert. All hardware, including a video camera for data collection, is enclosed within an 80/20 box with Plexiglas paneling.



Technology Maturation

- The current TRL of our project is level 4/5. To bring the TRL solidly to level 5, the device must be capable of air and liquid transfer within the two chambers of the cell culture compartment. It must also function autonomously.
- This equipment is designed for use in life sciences experiments; therefore, the final test of its functionality will necessitate biological cultures to bring the TRL to level 6. This will require a "recycling" flight that will contain biological cultures and cell culture reagents.
- A final test on a sRLV platform, with one sustained period of microgravity, will verify the fidelity of the device and all subsystems.

Objective of Proposed Experiment

- To test and verify the functionality of a fully automated cell culture apparatus that maintains an air-liquid interface.
- Test functionality of the gas-permeable, liquid-impermeable membrane and whether the design of the cell culture compartment is adequate for air and liquid exchange with minimal bubble formation.
- Expected flight data will be from visual observations and video camera recordings

Applicable Technology Areas: OCT Technology Area 06 – Human Health, Life Support, and Habitation Systems (TA06, HLHS).

028-P

A demonstrated application of a cost effective and novel platform for on-invasive acquisition of physiologic variables from spaceflight participant candidates

Problem Statement

- For NASA the area of human performance and health monitoring for human spaceflight is of continuing interest as specified by the Human Health, Life Support, and Habitation Systems roadmap.
- The Vital Space effort is focused on the development and implementation of innovative hardware and software solutions for the collection, storage, and retrieval of physiological data related to commercial spaceflight participants
- Users: Commercial spaceflight participants and equivalent counterparts

Technology Development Team

- **PI**: Ravi Komatireddy MD, Scripps Translational Science Institute. rkomat@scripps.edu

- **Funding**: NASA Flight Opportunities Program.

Partner Organizations:

- 1. Sotera Wireless Inc.
- 2. Astronauts For Hire
- 3. MEDgle Inc.
- 4. The Scripps Research Institute

Proposed Flight Experiment

Experiment Readiness:

- Experiment is flight ready.

Test Vehicles:

- Zero G Corporation – Boeing 727-200

Test Environment:

- Zero gravity, lunar gravity and Martian gravity environments.

Test Apparatus Description:

- Sotera Wireless Inc. – ViSi Mobile. Non-invasive, FDA approved real time physiological monitoring platform.

Photo and Graphics of the Hardware

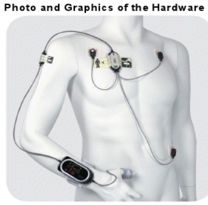


Figure 1: ViSi Mobile Biosensor Platform

Figure 2: ViSi Display and Control Unit

- Wireless Tablet PC
- Touch sensitive

Operator Interface

- OLED Display

Graphic of software display

Figure 3: ViSi Mobile Physiologic Data Output

Technology Area Addressed: TA06 Human Health, Life Support and Habitation Systems

Technology Maturation

- Testing basic operation, human interface, and anticipated failure modes
- Identifying areas of risk for users and the flight environment
- Equivalency and Superiority testing against gold standard medical devices
- Clinical, physiologic research with subjects in the parabolic and suborbital environment using the ViSi system to obtain medical data
- Flight testing to reach TRL 6 is needed ASAP

Objective of Proposed Experiment

- 1. Assess successful basic operation of the ViSi with respect to continuous physiological data capture in microgravity conditions.
- 2. Assess ease of use and interface between the ViSi hardware, software, and subject under varying gravity loads.
- Successful use of hardware data capture in microgravity will allow progression of testing to physiological performance analysis of commercial space participants.

042-P OSIRIS-REx Low-Gravity Regolith Sampling Tests

Problem Statement

- How to sample asteroids and comet nuclei
- The technology being tested is regolith fluidization and collection by gas injection
- This flight opportunity will test 5 sampler head regolith combination/flight to determine sample collection in low gravity
- Missions to sample asteroids e.g. OSIRIS-REx, and to sample comet nuclei

Technology Development Team

- Joe Vellinga is Principal Investigator, email: joseph.m.vellinga@lmco.com, Lockheed Martin Space Systems Company
- Arlin Bartels, GSFC, OSIRIS-REx Contract #NNG12FD66C with LMSSC
- GSFC, University of Arizona

Proposed Flight Experiment

Experiment Readiness:

- Ready for May 15 – 18, 2012 Flights; all equipment shipped 5/7/12

Test Vehicles:

- Parabolic aircraft

Test Environment:

- Sampling system flown in reduced gravity in 2007 and on FAST flights in 2009.
- Request reduced gravity parabolic flights at near zero gravity

Test Apparatus Description:

- One of 3 test fixtures shown (test chamber left, pressure control right); two additional test fixtures with two chambers each; five test chambers/flight

Technology Maturation

- TRL 6 achieved when sample collection of representative regolith demonstrated in the relevant environments
- Ground testing: ambient, vacuum, hot, cold
- Reduced gravity tests correlated with ground tests
- TRL 6 by 3/15/13 OSIRIS-REx PDR

Objective of Proposed Experiment

- Conduct sampling tests: 5 tests planned / flight with a range of regolith simulants
- Flight data is the sample collected of the range of regolith simulants
- Data to be compared to ground test data

Technology Areas addressed by this technology: 4.1.5 Robotics..& Autonomous Systems , 7.1.2 Resource Acquisition , 7.5.3 Remote Mission Operations

Schedule

- May 10 - Arrival at Ellington, get badges, check in, Safety Briefing, check payloads
- May 11 – Physio training, prepare payloads
- May 14 – Test Readiness Review, P/L integration to plane, Combined Systems Test
- May 15 – 18 – Flights: daily - pre-flight briefs, meds, flight, post-flight debrief, test results check
- May 18 or 19 – de-integrate payloads, prepare for shipping, clear out